

UNCLASSIFIED

AD NUMBER	
AD029253	
CLASSIFICATION CHANGES	
TO:	unclassified
FROM:	confidential
LIMITATION CHANGES	
TO:	Approved for public release, distribution unlimited
FROM:	Controlling DoD Organization: Office of Naval Research, Arlington, VA.
AUTHORITY	
31 Oct 1965 per Group-4, DoDD 5200.10; ONR ltr dtd 28 Jul 1977	

THIS PAGE IS UNCLASSIFIED

Armed Services Technical Information Agency

Because of our limited supply, you are requested to return this copy WHEN IT HAS SERVED YOUR PURPOSE so that it may be made available to other requesters. Your cooperation will be appreciated.

AD 29253

NOTICE: WHEN GOVERNMENT OR OTHER DRAWINGS, SPECIFICATIONS OR OTHER DATA ARE USED FOR ANY PURPOSE OTHER THAN IN CONNECTION WITH A DEFINITELY RELATED GOVERNMENT PROCUREMENT OPERATION, THE U. S. GOVERNMENT THEREBY INCURS NO RESPONSIBILITY, NOR ANY OBLIGATION WHATSOEVER; AND THE FACT THAT THE GOVERNMENT MAY HAVE FORMULATED, FURNISHED, OR IN ANY WAY SUPPLIED THE SAID DRAWINGS, SPECIFICATIONS, OR OTHER DATA IS NOT TO BE REGARDED BY IMPLICATION OR OTHERWISE AS IN ANY MANNER LICENSING THE HOLDER OR ANY OTHER PERSON OR CORPORATION, OR CONVEYING ANY RIGHTS OR PERMISSION TO MANUFACTURE OR USE OR SELL ANY PATENTED INVENTION THAT MAY IN ANY WAY BE RELATED THERETO

**Reproduced by
DOCUMENT SERVICE CENTER
KNOTT BUILDING, DAYTON, 2, OHIO**

CONFIDENTIAL

AD No. 200-2-53
ASTIA FILE COPY

CONFIDENTIAL

Technical Memorandum

**LAWS OF DYNAMIC SIMILITUDE
FOR
AERIAL PICKUP MODELING**

by
P. S. Chase

NOTICE: THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794. THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

NORTH AMERICAN INSTRUMENTS, INC.
2420 NORTH LAKE AVENUE
ALTADENA, CALIFORNIA

CONFIDENTIAL

54AA-19691

CONFIDENTIAL

COPY NO. 9

**NORTH AMERICAN INSTRUMENTS, INC.
2420 N. Lake Ave
Altadena, California**

**FEASIBILITY OF AERIAL PICKUP SYSTEMS
Office of Naval Research Contract Nonr-1279(00)
Project NR 221-003**

This document has been reviewed in accordance with
OPNAVINST 5110.5, paragraph 5. The security
classification is correct.

Date: 9/27/54

By J. V. Schuman
Chief of Naval Research (Code 461)

Technical Memorandum

**Laws of Dynamic Similitude
for Aerial Pickup Modeling**

by

P. S. Chase

October 27, 1953

THIS MATERIAL CONTAINS INFORMATION AFFECTING THE NATIONAL
DEFENSE OF THE UNITED STATES. IT IS THE POLICY OF THE
ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 AND 794, THE
TRANSMISSION OR REVELATION OF INFORMATION IN ANY MANNER TO AN
UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

CONFIDENTIAL

CONFIDENTIAL

-1-

Abstract

Similarity laws for the dynamic modeling of object trajectories and accelerations in various aerial pickup systems are presented.

CONFIDENTIAL

TABLE OF CONTENTS

	<u>Page No.</u>
Abstract	1
Table of Contents	ii
Introduction	1
Analysis	1
Discussion	4
References	7

Introduction

In evaluating the feasibility of certain aerial pickup systems, the need has arisen to extrapolate observed results from experiments at less than full scale to those which may be expected in the full-scale prototype. In the future it may be necessary to conduct model experiments on systems as yet untested.

The interpretation of model experimental data may be accomplished with the similarity laws involved. These laws are tabulated here for the dynamic modeling of aerial pickup phenomena.

Analysis

The problem of modeling static situations has been described in Ref. (a) and elsewhere. Modeling of certain specific dynamic phenomena has been described in Refs. (b) and (c). In the present discussion the techniques developed in these references are extended to the specific case of dynamic modeling for aerial pickup systems.

It is of prime importance that geometrical similarities be preserved between full-scale and the model; i. e., cable length, cable diameter, object dimensions, etc., must all be scaled by the same ratio.

Assume the relationship between the linear dimension (L) of full-scale and model is given by the ratio R. Then denoting full-scale conditions by the subscript ()_{fs} and model conditions by ()_m.

$$\frac{L_{fs}}{L_m} = R$$

Also assume that the ratio of velocity (V) between full-scale and model conditions is established by some criterion as yet unspecified. Therefore

$$\frac{V_{fs}}{V_m} = K$$

It is necessary to maintain the ratio of inertia forces to aerodynamic forces constant in the prototype and the model in order to preserve the similarity of vector force diagrams for any component. Therefore, since inertia forces are equal to mass (m) times acceleration (a) and aerodynamic forces are proportional to a force coefficient (C), the density (d) of the fluid, the velocity squared, and a length squared,

$$\frac{m_{fs} a_{fs}}{C_{fs} d_{fs} V_{fs}^2 L_{fs}^2} = \frac{m_m a_m}{C_m d_m V_m^2 L_m^2}$$

and the relationship between accelerations becomes:

$$\begin{aligned} \frac{a_{fs}}{a_m} &= \frac{m_m}{m_{fs}} \frac{C_{fs}}{C_m} \left(\frac{d_{fs}}{d_m} \right) \text{ fluid} \frac{V_{fs}^2}{V_m^2} \frac{L_{fs}^2}{L_m^2} \\ &= \frac{m_m}{m_{fs}} \frac{C_{fs}}{C_m} \left(\frac{d_{fs}}{d_m} \right) \text{ fluid} K^2 R^2 \\ \text{but } \frac{m_m}{m_{fs}} &= \left(\frac{d_m}{d_{fs}} \right) \text{ solid} \frac{L_m^3}{L_{fs}^3} \\ &= \left(\frac{d_m}{d_{fs}} \right) \text{ solid} \frac{1}{R^3} \end{aligned}$$

$$\text{and } \frac{a_{fs}}{a_m} = \left(\frac{d_m}{d_{fs}} \right)_{\text{solid}} \left(\frac{d_{fs}}{d_m} \right)_{\text{fluid}} \frac{C_{fs}}{C_m} \frac{K^2}{R}$$

Since time (t) equals velocity divided by acceleration the time relationship is,

$$\begin{aligned} \frac{t_{fs}}{t_m} &= \frac{V_{fs}}{a_{fs}} \frac{a_m}{V_m} \\ &= \left(\frac{d_{fs}}{d_m} \right)_{\text{solid}} \left(\frac{d_m}{d_{fs}} \right)_{\text{fluid}} \frac{C_m}{C_{fs}} \frac{R}{K} \end{aligned}$$

If it is of interest to investigate angular velocities, the criterion is that helix angles in the full-scale phenomena be duplicated in the model phenomena. Helix angle is equal to angular velocity (W), times a characteristic length, divided by velocity. Therefore,

$$\frac{W_{fs} L_{fs}}{V_{fs}} = \frac{W_m L_m}{V_m}$$

$$\text{and } \frac{W_{fs}}{W_m} = \frac{K}{R}$$

Since angular acceleration (A) is equal to linear acceleration divided by a characteristic length, the ratio of angular accelerations becomes:

$$\frac{A_{fs}}{A_m} = \frac{a_{fs}}{L_{fs}} \frac{L_m}{a_m}$$

$$\text{and } \frac{A_{fs}}{A_m} = \left(\frac{d_m}{d_{fs}} \right)_{\text{solid}} \left(\frac{d_{fs}}{d_m} \right)_{\text{fluid}} \frac{C_{fs}}{C_m} \frac{K^2}{R^2}$$

Although it does not appear to be of great importance in the present case, it has been shown in Ref. (b) that the relationship of moment of inertia between the full-scale prototype components and those of the model must be

$$\frac{I_{fs}}{I_m} = R^5 \left(\frac{d_{fs}}{d_m} \right)_{\text{Solid}}$$

Discussion

It will be noted that in modeling aerial pickup systems it is most convenient if the acceleration of gravity is identical in the full-scale case and the model case, although for exact modeling it should be scaled up in accordance with the previously given law of similarity for linear accelerations. Therefore vertical heights of observed trajectories in the model are too large and must be corrected accordingly by subtracting the displacement error due to gravity. If the times of action in the model are small, the modeling error due to gravity will be negligible.

The ratio of velocity between full-scale and model may now be considered, since it may be determined as a matter of convenience, but only within a certain range which will be specified by the Reynolds number of full-scale and model tests. It is necessary to duplicate Reynolds number (the ratio of inertia to viscous forces in the fluid) in order to obtain exact geometrical similarity of flow conditions.

The various types of systems to be investigated will determine the relative importance of the factors described above. In some instances, it may be more important to duplicate inertia effects and in others aerodynamic effects. However, the dynamic similarity laws are not incompatible, and for a large number of systems of interest, very good modeling should be possible.

If it is assumed that model experiments will be made in air,

$$\left(\frac{d_{fs}}{d_m} \right)_{\text{fluid}} = 1,$$

and if identical materials are used in full-scale and model components,

$$\left(\frac{d_{fs}}{d_m} \right)_{\text{solid}} = 1$$

If Reynolds numbers are duplicated

$$C_{fs} = C_m$$

and the laws of similarity may be summarized as follows:

$$\frac{L_{fs}}{L_m} = R$$

$$\frac{V_{fs}}{V_m} = K$$

$$\frac{a_{fs}}{a_m} = \frac{K^2}{R}$$

$$\frac{t_{fs}}{t_m} = \frac{R}{K}$$

$$\frac{W_{fs}}{W_m} = \frac{K}{R}$$

$$\frac{A_{fs}}{A_m} = \frac{K^2}{R^2}$$

$$\frac{I_{fs}}{I_m} = R^5$$

CONFIDENTIAL

-7-

REFERENCES

- (a) Taylor, D. W., "Some Aspects of the Comparison of Model and Full-Scale Tests," NACA Report 219, 1926.
- (b) Scherberg, M., and Rhode, R. V., "Mass Distribution and Performance of Free Flight Models", NACA Technical Note 268, October 1927.
- (c) Neihouse, A. I., and Pepoon, P. W., "Dynamic Similitude Between a Model and Full-Scale Body for Model Investigation at Full-Scale Mach Number", NACA Technical Note 2062, March 1950.

CONFIDENTIAL